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PERFORMANCE AND EMISSION CHARACTERISTICS OF BIOGAS –PETROL DUAL FUEL IN SI ENGINE

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ABSTRACT

Towards the effort of reducing the dependency on petroleum fuel, one of the solutions is to use gaseous fuel as a partial supplement of liquid petrol fuel. In this experiment, four cylinder SI engine was tested with petrol as a fuel and petrol with partial substitution of biogas as fuel. Different percentages of biogas substitution in petrol were tested like B10 (90% Petrol +10% biogas), B20(80% Petrol +20% Biogas), B40(60%Petrol +40% Biogas). Test was conducted to study and compare the performance, emission and combustion characteristic of the engine for both the modes of engine operation. Biogas production was carried out using kitchen waste as a feedstock. Results clearly revealed that performance of the engine improved with the increases in amount of the gas substitution. Bsfc and brake thermal efficiency were found to improve. However emissions increased with the increases in the amount of gas substitution.

Keywords: Performance, Emission, 4stroke Petrol, Combustion, Biogas

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1. INTRODUCTION

The increased use of automobiles and the rapid rate of industrial development in the world made petroleum supplies unable to keep up with demands. Moreover, petroleum fuels pollute the environment with their combustion products. Control devices were used to reduce pollution, but resulted in about 15% reduction in the vehicle mileage. It is, therefore, worthwhile to look into the suitability of using “clean” burning fuels for use in spark ignition engines (S.I). There is a need to conserve petroleum resources by its judicious use and by substituting it by other alternatives wherever feasible. Using of alternative fuels maybe achieved by

converting an existing engine to operate on either the original fuel and the alternative fuel “dual fuelling” or, in general, a specially designed engine for the new fuel will offer better performance. In the field of ICE, gaseous fuels have become a good alternative to traditional petroleum derived fuels, such as diesel and gasoline.

Biogas is one such a fuel and an attractive source of energy for rural areas. It can be produced from cow dung and other animal wastes and also from plant matter such as leaves and water hyacinth-all of which are renewable and available in the countryside. It is generated during the anaerobic (out of contact with air) digestion of organic matter-cow dung and leaves. It is approximately two-thirds (by volume) methane (CH4) and the rest CO_2. It is produced by bacteria, which break down organic material under air less conditions.

This process is called ‘‘anaerobic digestion’’[1].Many research efforts provide a review on the potential biogas production and its application, as a gaseous fuel in Internal Combustion (IC) engines. Methane (CH4) is the main component (about over 65% by vol.) of the biogas and exhibits greater resistance to the knock phenomenon due to its higher octane rating and auto-ignition temperature, making it appropriate for engines with high compression ratios [2,3]. E. Porpatham et al. [4] did experimental investigation on a single cylinder diesel engine which was modified to operate as a biogas operated spark ignition engine. The engine was operated at 1500 rpm at throttle opening of 25% and 100% at various equivalence ratios. At higher compression ratios above 13:1, increased NOx, HC, and CO emissions were measured. There is an improvement in thermal efficiency and brake power output with increase in compression ratio.

The objective of this study was to investigate the influence of dual fuel combustion on the engine performance and exhaust emission in SI engine fuelled with biogas-petrol dual fuel. For this reason engine test were carried out on SI engine using neat petrol as fuel and biogas-petrol as dual fuel. Different percentages of biogas substitution were used to compare the performances and exhaust emission.

2. EXPERIMENTAL METHODOLOGY

This work is an attempt to evaluate the effects of biogas substitution with petrol on the performance, emissions and combustion of a spark ignition engine. The test system for this experimental analysis includes a compact biogas plant and a four cylinder spark ignition engine. For the purpose of experiment the set up has to be modified and equipped with additional systems. Biogas production was carried out at portable biogas plant at the college of engineering campus. Experiments were done for engine operated on 100% petrol, 90% petrol-10%biogas, 80%petrol-20%biogas, 60%petrol - 40%biogas.

The experimental work started with biogas production. Compact Biogas system is made from two cut-down standard high density polyethylene water tanks and standard plumber piping. The larger tank acts as the container containing the waste material while the smaller one is inverted and telescoped into this larger one. This smaller inverted tank is the floating gas chamber, whose rise is proportional to the produced gas and acts as a storage space for the gas.

Space of about 2 m^2 area 2.5 m height is needed for 1000 liters. The effective volume of the digester is approximately 850 liters, given by the dimension of the 1000 liter water tank (inner radius: 51.5 cm) and the position of the overflow- pipe (1.04 m above ground level). Roughly 0.6 m^2 (78%) of the total surface area of the digester (0.83 m^2) is covered by the gasholder

Table 1 Biogas plant analysis

Substrate	Mean Temp (ºC)	Mean pH	No. of days ($0.4m^3$)	Amount (kg)
Animal Dung	24.25	6.2	44-45	50-55
Kitchen Waste	28.28	6.24	9	3-3.5
Fruits Waste	31.5	6.6	7	2-2.5

The experimental system is represented in Figure 3.2. The setup consists of regulating and metering devices for air and fuel, test engine, a dynamometer, an electronic engine control unit (ECU), a computer-based in-cylinder pressure and crank angle measurement system, a compact biogas plant, and an exhaust gas analyzer. Tests were performed while operating the engine at a constant speed and variable load. In these tests, parameters such as brake power, air and fuel flow rates, exhaust emissions and in-cylinder pressure were measured. By varying the throttle position and fuel flow rate, desired engine power output could be obtained.

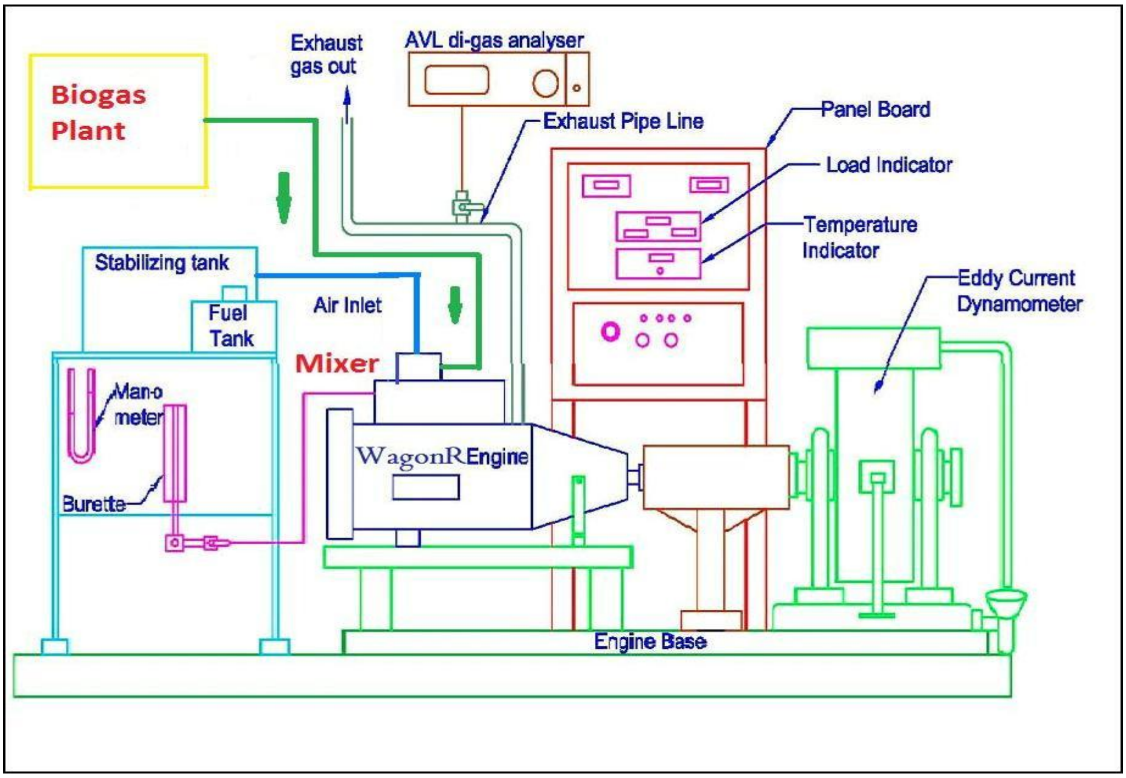

Figure1 Experimental Setup

The engine was run using biogas, which is obtained from the compact biogas plant containing nearly 60% methane (CH4) and 40% carbon dioxide (CO2) by volume. Biogas flow was controlled using a manually operated needle. A pressure regulator

was used to reduce the biogas pressure (to 0.1 bar) in order to simulate the low-pressure biogas generated in typical biomass digesters. A volume flow meter was used to measure the biogas flow rate. A throttle valve was used to control the amount of air being transferred to the engine cylinder from the air filter. The air flow was measured using an orifice flow meter. Apart from these measurements, carbon monoxide and hydrocarbons were also measured using exhaust gas analyzer.

Table 2 Engine Specification

Type -	Value
Make	
Engine Type	16 Valve 1.1 litre
Bore × Stroke	69 × 72 (mm)
Compression ratio	10:1
Rated Power	50 kW @ 6200 rpm
No. of cylinders	4
Cooling System	Water Cooled

Table 3 Fuel Properties

Properties	Petrol	Biogas
Density (kg/ m^3)	740	1.2
Octane Number	100	130
Lower Heating Value (MJ/kg)	44	30
Stoichiometric air-fuel ratio (AFR)	14.5	10

3. EXPERIMENTAL RESULTS AND DISCUSSION

Experimental results of the tests performed on the engine are presented below. The variation in percentage of gas substitution will alter combustion characteristics due to differences in their properties. For example, CO and methane in blend will decrease the speed of the flame and CO_2 will act as diluents, decreasing the speed and the temperature of the flame [12]. Discussion of combustion results allows conclusions regarding the behaviour of these blends as fuel.

3.1. Heat Release Rate

Figure 2. shows the typical cylinder pressure curves for Petrol and different blends of petrol and biogas (B10, B20, and B40) tested for working conditions: 2500 rpm at full load. As it can be observed, the evolution of the pressure curves depends on the combination of methane, CO_2 in fuel composition, together with the dilution produced by the air excess.

Lowest pressures are generated by the combustion of biogas. This is caused by the high fraction of CO2 in its composition, which origins flat pressure curves with a maximum peak angle between syngas 1 and methane. The use of lean conditions

implies, in general, a decrease in maximum pressures. In biogas combustion is detoriated which results in a significant fall in maximum pressure

The heat release rate for petrol and dual fuel mode of engine operation at a constant engine speed of 2500 rpm is shown in figure. It interprets heat release rate results calculated for petrol and three different sets of dual fuel mode of engine operation. As viewed in Figure 3, maximum heat rates are obtained with petrol as compared to dual fuel mode. Biogas presents the lowest and slowest process of heat release because the fuel energy is spent in changing the temperature of the high fraction of CO_2 present in this blend instead of generating power. It is evident as the percentage of gas substitution increases in the dual fuel mode reduction in heat release rate is observed. Maximum heat release rate is obtained for petrol followed by B10, B20 and the least value is obtained for B40.

3.2. Brake Thermal Efficiency

Comparison of brake thermal efficiency variation with brake power for neat petrol and different blends of biogas with petrol has been done. From the above figure 4, it is evident that brake thermal efficiency increase with increase in the percentage of gas substitution. It is observed that the value of brake thermal efficiency at lower load with minimum gas substitution of 10% is very close to that of neat petrol. Biogas has wide flammability limit and can easily form a homogeneous mixture with air for good combustion which increases brake thermal efficiency.

At higher engine speed of 2500 and 3500 rpm brake thermal efficiency was improved even more.15% of increase in brake thermal efficiency was evident for B40 in comparison with neat petrol. And at 3500 rpm of engine speed increase of about 17% was observed for B40 in comparison with neat petrol

3.3. Brake Specific Fuel Consumption

The brake specific fuel consumption (bsfc) of the engine for both Petrol and Dual Fuel mode were found to be high at low loads, decreased sharply to a minimum near the rated capacity as is shown in Figure 5 For running with biogas the rates of specific fuel consumption sharply decreased with loading. Specific fuel consumption was improved with the increase in biogas percentage in dual fuel (Petrol + Biogas)

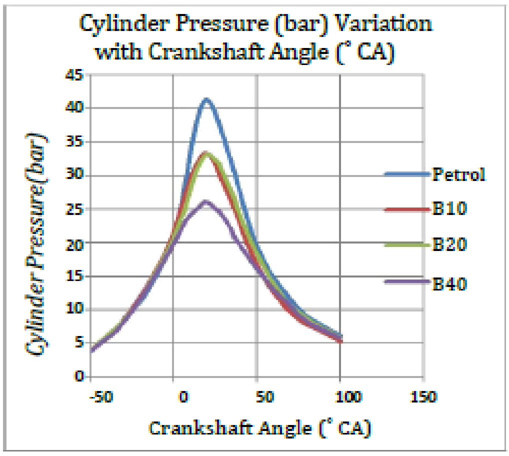

Figure 2 : Cylinder Pressure versus crank angle

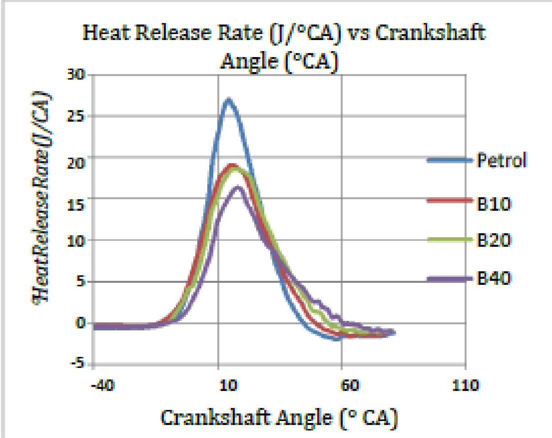

Figure 3 : Heat Release Rate versus crank angle

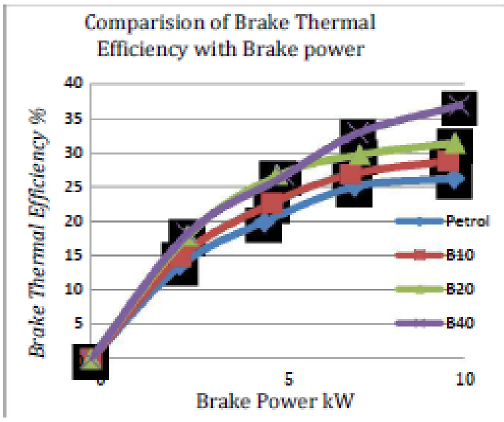

Figure 4 : Brake thermal efficiency v/s power

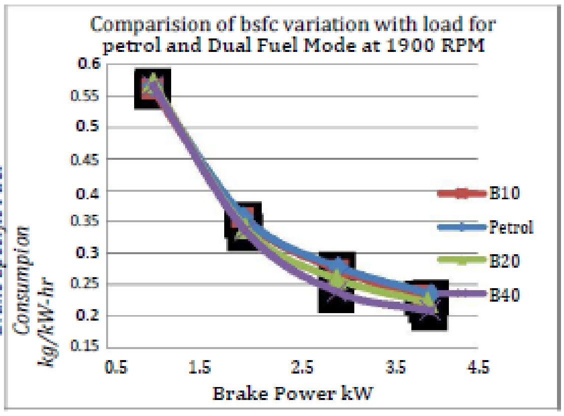

Figure 5 : bsfc versus brake power

For B40 (60% Petrol + 40% Biogas) bsfc was observed to be the least. Moreover, for different engine trials of constant speed variable load more improvement in bsfc was observed at higher rpm.

At 1900 RPM of engine speed with low load bsfc was observed to be very close for petrol and the other blends of biogas i.e. B10, B20,B40. But as the load increased dual fuel mode showed improvement. In comparison with neat petrol and blends of biogas with petrol maximum improvement is observed for B40 (60%petrl +40% biogas). B40 shows decrease in bsfc by 8% in comparison with neat petrol. Whereas for the blends of B10 and B20 bsfc decreased by 3.5% and 5% respectively

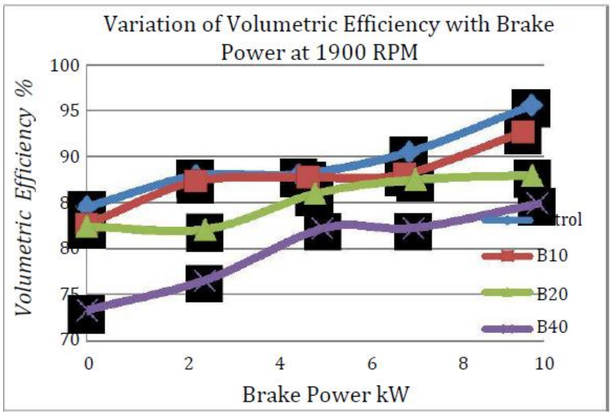

Figure 6 Volumetric efficiency v/s power

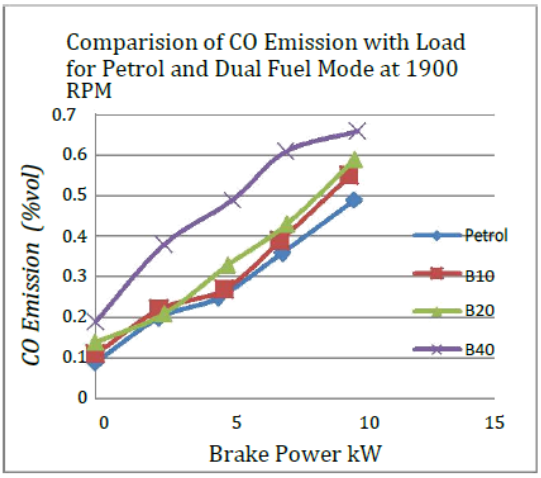

Figure7 CO emission V/s brake power

3.4. Volumetric Efficiency

The volumetric efficiency of the dual fuel engine shown in figure 6 is obvious to drop since biogas is inducted into the cylinder with the air which has lower density than air and hence requires more mass to occupy the volume of cylinder which ultimately reduces the breathing capacity of the engine.

3.5. CO Emission

Above figure 7 shows CO emission for petrol and dual fuel mode. In comparison between petrol and dual-fuel combustions, the concentrations of CO emissions for the dual-fuel mode with all the percentages of gas substitution (B10, B20, B40) were considerably higher than those of the petrol mode under all test conditions. With the inducing of gaseous fuel (biogas), which means the increasing of the CO2 content in the mixture instead of fresh-air, turbulent flame propagation from the ignition regions of the pilot is normally suppressed due to the lower temperature and air–fuel ratio, and it will not proceed until the concentration of the gaseous fuel reaches a minimum limiting value.

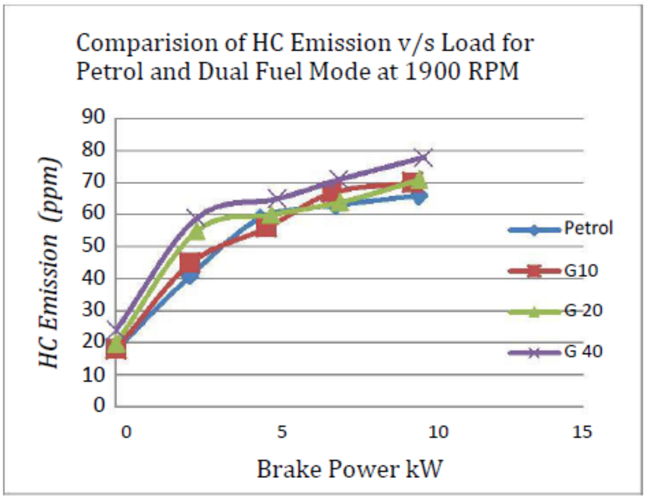

Figure 8 HC emission v/s Power

Also, it has been reported that the ignition is normally more delayed with dual-fuelling compared to petrol fuelling. In addition to these mechanisms, there were contributions from crevice volumes in which the gas–air mixture was forced into during compression and where it then remains unburned. CO emission is observed to increases with load for both petrol and dual fuel mode. As the substitution of gas increased Co emission were increased. B40(60% petrol + 40 % biogas) happened to emit the most. There was an increase in CO emission by 20% when compared for B40 and petrol. For B10 (90% Petrol + 10% biogas) CO emission increased by 8% whereas by B20 CO emission increased by 12%.

3.6. HC Emissions

Figure 8 shows HC emission variation with load for petrol and Dual fuel mode. In dual fuel mode three different sets of combination of biogas and petrol were tested (B10, B20, B40). Plotting the results made a clear observation that hydrocarbon emission increases with the increases in the amount of gas substitution in dual fuel mode. For all the combinations of dual fuel i.e B10, B20, B40, HC tends to increase in comparison with petrol. However highest hydrocarbon emission are shown by B40(60% Petrol+40% Biogas).

The increases in hydrocarbon emission is due to the composition of biogas which consist of nearly 60% of CH_4 and 40% of CO_2. So as the percentage of biogas increases the amount of Hydrocarbons also increases. Thus it can be seen that HC emissions are highest for 40% of biogas with petrol which decreases for 20% and 10% of blends and minimum for petrol. So it is evident that least HC emission are observed for petrol which increase when engine is run on dual fuel mode with gas substitution of 10% (B10) further increases for gas substitution of 20% (B20) and highest is marked for gas substitution of 40% (B40)

4. CONCLUSION

Performance Testing revealed that Brake specific fuel consumption and Brake thermal efficiency were improved with increases in gas substitution. It was evident from the results that B40 obtained maximum improvement in bsfc by 12% and brake thermal efficiency was increases by 17%. However there was a decrease in volumetric efficiency with the increases in gas substitution. B20 also exhibited similar results with improvement in bsfc by 8% and increases in brake thermal efficiency by 12%. B10 results in improvement in bsfc and brake thermal efficiency when compared to petrol but observed more bsfc and lower brake thermal efficiency when compared with B20 and B40.

6] Emission Testing revealed that CO and HC Emission increases as the amount of gas substitution increases. Petrol observed to emit least CO and HC, followed by B10 and B20 and maximum emission were obtained for B40 (60% Petrol+ 40% Biogas).

7] Percentage reduction in petrol consumption was calculated on energy basis. it can be concluded that with dual fuel mode, reduction in petrol consumption in evident. For B10 on energy basis percentage reduction in petrol consumption is about 16.5 %, for B20 on energy basis percentage reduction in petrol consumption is about 28.3% where as maximum reduction in petrol consumption of about 50.19% is revealed by B40

8] Combustion Analysis was done. In cylinder pressure variation with crankshaft angle was recorded for petrol and dual fuel mode of engine operation. Using this data

estimation of heat releases rate was done using GT POWER. Results revealed that heat release rate decreases with increases in gas substitution. Lowest heat release rate was obtained for B40.

Thus, after analysis all the three parameter i.e performance, emission and combustion, it can be concluded that B20 (80% Petrol + 20% biogas) would be best mode of dual fuel operation as it gives improvement of bsfc by 8%, increases in brake thermal efficiency by 12%, relatively lower CO and HC emission than B40 and Percentage reduction of petrol consumption of about 28 % (energy basis)

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